LOW-DEGREE PARTIAL MELTING EXPERIMENTS OF CR AND H CHONDRITE COMPOSITIONS: IMPLICATIONS FOR ASTEROIDAL MAGMATISM RECORDED IN GRA 06128 AND GRA 06129.

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Introduction: Studies of differentiated meteorites have revealed a diversity of differentiation processes on their parental asteroids; these differentiation mechanisms range from whole-scale melting to partial melting without the core formation [e.g., 1]. Recently discovered paired achondrites GRA 06128 and GRA 06129 (hereafter referred to as GRA) represent unique asteroidal magmatic processes. These meteorites are characterized by high abundances of sodic plagioclase and alkali-rich whole-rock compositions, implying that they could originate from a low-degree partial melt from a volatile-rich oxidized asteroid [e.g., 2, 3, 4]. These conditions are consistent with the high abundances of highly siderophile elements, suggesting that their parent asteroid did not segregate a metallic core [2]. In this study, we test the hypothesis that low-degree partial melts of chondritic precursors under oxidizing conditions can explain the whole-rock and mineral chemistry of GRA based on melting experiments of synthesized CR- and H-chondrite compositions.

Experiments: Melting experiments were conducted using a gas-mixing furnace at ambient pressure with an oxygen fugacity (fo_2) near IW+2. The fo_2 was controlled using flowing CO/CO_2 gas mixtures. The experiments employed synthesized H- and CR-chondrite compositions [5, 6] as starting materials. The starting compositions were hung on Re-wire loops and heated at three different temperatures (1200, 1150 and 1130 °C) for 48-65 hours. To obtain melt pockets large enough to analyze, the samples were first heated at 1300 °C for 1 hour before dropping to the target temperatures. Experimental charges were analyzed using standard electron microprobe (EMPA) techniques. Weight fractions of phases present in the run products were determined by mass balance calculations. The mass balance calculation also evaluated Na loss during the experiments and EMPA analyses.

Results: All experimental charges contain olivine and glass with minor spinel and FeNi metal. Plagioclase is present only in the lowest-T experiment using the CR-chondrite composition (Table 1 and Fig. 1b). All phases, except for spinel and some olivines in the low-T (1150 and 1130 °C) charges, are typically homogeneous. The Fe-Mg exchange coefficient (K_D) values between olivine and glass suggest that the experiments closely approached equilibrium (Table 1). No significant Na or Fe losses were observed.

Olivine is the most abundant phase (>80%) and is euhedral to subhedral. Glass and plagioclase occur interstitially between the olivine grains (Fig. 1). Olivine has compositions near Fo_{55} and Fo_{57} for the H- and CR-chondrite experiments, respectively. Higher-T experiments yield slightly higher Fo olivines. NiO and Cr_2O_3 contents decrease but CaO increases with decreasing temperature. Plagioclase has a composition near $An_{68}Ab_{31}Or_{<1}$.
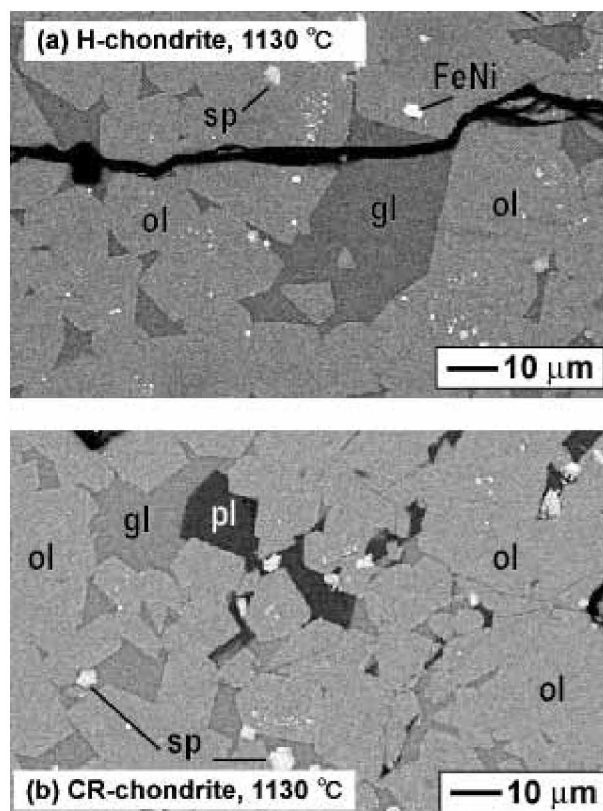
Figure 1: Back-scattered electron images of experimental charges at T = 1130 °C. Abbreviations: ol = olivine, pl = plagioclase, gl = glass, sp = spinel, FeNi = FeNi metal.

Glass is characterized by low silica and high alkali contents (39-43 wt% SiO_2 and 1.8-4.9 wt% Na_2O; Table 1), resulting in silica-undersaturated (nepheline normative) compositions. Broadly speaking, the melts in our experiments could be characterized as alkali angrites. Consequently, our olivines are fairly calcic (~0.5 wt.% CaO). Melt fraction varies from 0.14 to

0.21 and 0.095 to 0.18 for the H- and CR-chondrite experiments, respectively. With decreasing melt fractions, concentrations of alkali elements (Na and K) increase until the appearance of plagioclase, while those of other incompatible elements such as P and Ti progressively increase (Fig. 2).
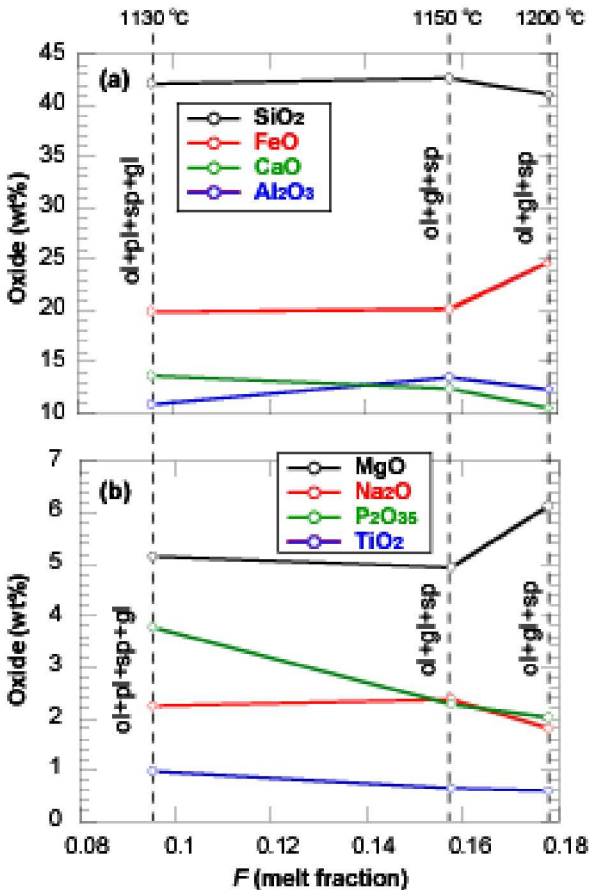

Figure 2: Selected oxide contents in the glasses for the CR chondrite experiment, versus melt fraction (F).

Discussion: Our study reinforces the general conclusion that partial melts of chondrites, generated under oxidizing conditions, are silica-undersaturated because of their high FeO contents [6,7]. Although our angritic low-degree silica-undersaturated melts are enriched in alkali elements, they cannot be parental to GRA that consists mainly of sodic plagioclase (Ab$_{>85}$). These angritic melts are inconsistent with not only the presence of orthopyroxene but also low-Ca contents (~0.1 wt%) in olivines and low-Al contents in pyroxenes (e.g., ~0.2 wt% for the orthopyroxene) in GRA [4].

Therefore, we arrive at a quandary. Almost all petrogenetic models for GRA require oxidizing conditions (≥IW) to explain the relatively high Fe/Mn ratios in the mafic minerals, the low Fo content of the GRA

olivines, the calculated Fe^{3+} contents of the GRA clinopyroxenes, and GRA's high siderophile element abundances [2,4]. However, all experiments to date, on oxidized chondritic materials (>IW), have produced angritic (i.e., silica-undersaturated) melts. Although greatly enriched in alkalis relative to angrites proper, our experiments are no exception, in that they have only ~40 wt.% SiO$_2$. Angritic-like minerals are not found in GRA.

Possibly there is a region of fo$_2$ where both the oxidized nature of GRA and its non-angritic mineralogy can be explained, but at present this seems difficult. It is possible that either a complex history [4] or a unique parent body is required for GRA petrogenesis.

Table 1: Melt compositions

Sample	H-chondrite			CR-chondrite		
T (°C)	1200	1150	1130	1200	1150	1130
SiO$_2$	38.8	40.2	42.5	41.1	42.7	42.2
TiO$_2$	0.64	0.67	0.80	0.60	0.65	0.98
Al$_2$O$_3$	11.3	13.4	14.0	12.4	13.6	10.9
FeO	27.9	22.0	19.6	24.7	20.2	19.9
MnO	0.26	0.22	0.20	0.22	0.17	0.17
MgO	5.65	4.38	4.38	6.14	4.95	5.17
CaO	10.1	10.5	11.5	10.6	12.4	13.7
Na$_2$O	2.91	4.89	3.73	1.81	2.39	2.25
K$_2$O	0.23	0.52	0.43	0.17	0.21	0.31
P$_2$O$_5$	1.50	2.36	2.27	2.03	2.29	3.78
NiO	0.19	0.15	0.14	0.14	0.15	0.18
Total	99.4	99.3	99.6	99.9	99.7	99.7
F	0.21	0.13	0.14	0.18	0.16	0.095
*K_D	0.28	0.28	0.30	0.31	0.31	0.34
**Phases	ol	ol	ol □	ol	ol	ol+pl

* Fe-Mg exchange coefficient between olivine and liquid.

** Spinel and FeNi metal are also present as minor phases.

References: [1] Mittlefehldt D. W. et al., in *Planetary Materials*, Papike J. J., Ed. (Mineralogical Society of America, Washington, D. C., 1998), vol. 36, pp. 1-195. [2] Day J. M. D. et al. (2009) *Nature, 457*, 179-182. [3] Shearer C. K. et al. (2008) *American Mineralogist 93*, 1937-1940. [4] Shearer C. K. et al. (in press) *GCA*. [5] Kallemeyn G. Y. et al. (1994) *GCA 58*, 2873-2888. [6] Jurewicz A. J. G. et al. (1995) *GCA 59*, 391-408. [7] Jurewicz A. J. G. et al. (1993) *GCA 57*, 2123-2139.